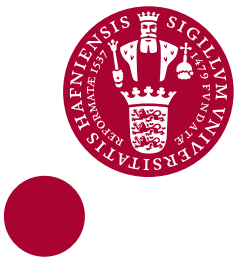

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Article

Do Current European Policies Prevent Soil Threats and Support Soil Functions?

Nadia Glæsner [1,2,*], Katharina Helming [1] and Wim de Vries [3]

[1] Directorate, Leibniz Centre for Agricultural Landscape Research (ZALF), Müncheberg 15374, Germany; E-Mail: helming@zalf.de

[2] Department of Plant and Environmental Sciences, University of Copenhagen, Thorvaldsensvej 40, Frederiksberg 1871, Denmark

[3] Alterra, Wageningen University and Research Centre (WUR), P.O. Box 47, Wageningen 6700 AA, The Netherlands; E-Mail: wim.devries@wur.nl

* Author to whom correspondence should be addressed; E-Mail: nadia.glaesner@gmail.com; Tel.: +45-2614-7726.

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Abstract: There is currently no legislation at the European level that focuses exclusively on soil conservation. A cross-policy analysis was carried out to identify gaps and overlaps in existing EU legislation that is related to soil threats and functions. We found that three soil threats, namely compaction, salinization and soil sealing, were not addressed in any of the 19 legislative policies that were analyzed. Other soil threats, such as erosion, decline in organic matter, loss of biodiversity and contamination, were covered in existing legislation, but only a few directives provided targets for reducing the soil threats. Existing legislation addresses the reduction of the seven soil functions that were analyzed, but there are very few directives for improving soil functions. Because soil degradation is ongoing in Europe, it raises the question whether existing legislation is sufficient for maintaining soil resources. Addressing soil functions individually in various directives fails to account for the multifunctionality of soil. This paper suggests that a European Soil Framework Directive would increase the effectiveness of conserving soil functions in the EU.

Keywords: European Union; soil policy; soil degradation; soil conservation; soil threats; soil functions; grand societal challenges; DPSIR

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1. Introduction

Despite growing pressures on European soils and the danger that these pressures pose to the services that healthy soils provide, there is no common EU policy on soil protection. In 2002, the Commission presented its approach to soil protection in a Communication that was titled "Towards a Thematic Strategy on Soil Protection" [1]. The main threats that lead to soil degradation were identified as erosion, decline in organic matter, contamination, sealing, compaction, loss of biodiversity, salinization and floods and landslides. Floods and landslides were later addressed in a separate Directive on flood risk management prevention (2007/60/EC) and have therefore been excluded from the Thematic Strategy on Soil Protection. The Commission stressed the importance of integrating soil aspects into other directives, but also indicated the need for legislation that focuses exclusively on soil. To fill the gap in European environmental legislation and to provide a more holistic approach to soil protection in the EU, the European Commission presented a new policy in 2006 that was titled "Thematic Strategy for Soil Protection" [2]. This followed a comprehensive stakeholder consultation and included a proposal for a Soil Framework Directive [3]. However, the proposal was not adopted. Germany, France, The Netherlands, the United Kingdom and Austria opposed the proposal [4] on the grounds of the subsidiarity and proportionality principles, expected costs and the administrative burden. They also questioned the value that the new policy added to existing Union law [5]. The proposal had been pending since 2006, but was finally withdrawn in May 2014 [6], because the Soil Framework Directive had been pending for eight years during which time no effective action had been taken [7].

The Impact Assessment (IA) [8] that supplemented the proposed Soil Framework Directive was focused on the costs of soil degradation, which were divided into different soil threats. Impact assessment (IA) has been an obligatory EU tool for achieving evidence-based policymaking since 2002 for all new directives to address the three pillars of sustainability, *i.e.*, social, environmental and economic impact. However, the IA could not justify the activity at the European level, because it provided little evidence of the impacts of soil threats. Estimates of the costs of soil degradation and soil threats at the European level were speculative, because the impacts of soil degradation on societal challenges, such as food production, could not clearly be shown, as the range of economic evaluation for each threat was very large and the estimations were not precise enough. Ongoing activities under the EU Soil Thematic Strategy are therefore currently narrowed to raising awareness, conducting research and integrating policies [9].

In addition to identifying soil threats, the 2006 proposal for a Soil Framework Directive introduced the functions that soil provides for humankind, but the impacts on those functions of measures to ameliorate the threats were not mentioned, even in a qualitative sense. Within research, focus has shifted from soil degradation (soil threats) to soil functions in the last decade [10–12]. This is reflected in the international conferences that were titled the "*Wageningen Conference on Applied Soil Science*" that was held in The Netherlands in 2011 [13] and "*Protection of soil functions—challenges for the future*" that was held in Pulawy, Poland in October, 2013. [14]. The concept of soil functions originates from a descriptive analysis by Blum [15]. Bouma [16] further elaborated on soil functions as a fundamental concept for linking soil science to policy and decision support. Indeed, the concept of soil functions can be seen as an early embodiment of the concept of ecosystem functions and services. The ecosystem service concept was developed to express the value of nature to human societies [17]. This

concept is used to formulate policy recommendations or, more generally, to support decision-making and is relevant at the interface of science and policy, where it can play two roles: it can translate the link between ecological processes and human wellbeing in a way that is understood by decision makers, and it can also communicate the scientific knowledge that is relevant to decision-making [18,19]. Considering the importance of the services provided by terrestrial ecosystems, Dunbar *et al*. [20], for example, evaluated the impact of various EU policies (Common Agricultural Policy (CAP), Biodiversity Strategy 2020, Habitat Directive, Bird Directive, Soil Thematic Strategy) on those services. The ecosystem service concept distinguishes between "functions", which are defined as the "capacity of ecosystem components and processes to provide goods and services that satisfy human needs" [21] and "services", which are defined as the actual "benefits people derive from ecosystems" [17]. The concept of soil functions seems to include both [12,16].

Current grand societal challenges have been identified at the EU level in "Horizon 2020", which is the Common EU Framework for Research and Innovation (2014–2020). "Horizon 2020" is intended to secure Europe's global competitiveness. The main soil-related challenges to competitiveness are food security, energy security and resource-use efficiency. Food security is becoming increasingly important in light of the growing worldwide food demand that results from an expanding and wealthier world population. Increased resource-use efficiency ("doing more with less") is crucial to increasing the production of food, feed and energy crops while reducing the use of resources, such as energy, water, land and nutrients, and reducing environmental impacts. The maintenance of soil resources plays a vital role in meeting these grand societal challenges and underpins the actuality of the topic of soil protection.

Current EU strategies and communications that are related to soil challenges include the 7th Environmental Action Programme (7 EAP) and the Resource Efficiency Roadmap (COM/2011/571), which are leading to a revival of the political discussion of the importance of soil protection in Europe. This was reflected in the communication from the European Commission (EC) on the implementation of the soil thematic strategy [9], which argues that the status of soil degradation remains alarming despite considerable efforts to raise awareness, conduct research and integrate policies. Information about the continued soil degradation throughout Europe is gathered in the European Soil Data Centre (ESDAC) [22]. This is done with the aim of not only presenting information relevant for soil policies, but also for other policies, such as CAP, climate change policy, the EU forest action plan, rural development and water management, further illustrated in a recent report by the Joint Research Centre [23]. The report estimates that 20% of European soils are being eroded by water and wind. The 7 EAP sets this at 25%. Within the 34 European countries in Europe (EU 28 plus Norway and Balkan States), moderate and high levels of land susceptibility to wind erosion are further predicted, corresponding to 5.3 and 2.9% of total area [24]. Spatial maps of European soils have been created for estimating organic matter content [25] and soils subject to salinization [26], indicating that 45% of European soils have a low organic matter content (defined as having less than 2% organic carbon) and that 3.8 million ha of soil are subject to salinization [23]. European subsoils have been classified into very high (9%), high (28%), moderate (44%) and low (20%) susceptibility to compaction [27]. This implies that more than a third of the European subsoils are classified as having a high or very high susceptibility to compaction. Potential contaminated sites are estimated to more than 2.5 million, and identified contaminated sites are around 342 thousand [28]. Further, at least 275 ha of soil per day is

lost to permanent soil sealing [23]. Finally, soil biodiversity is reported to be declining throughout Europe, mainly because of the abovementioned soil degradation processes. These trends appear to indicate that current legislative action is not adequate, especially considering that safeguarding important soil functions at the European level is a necessary precondition for meeting the upcoming grand societal challenges. The proposal to withdraw the Soil Framework Directive stated that it "opens the way for an alternative initiative in the next mandate" [7].

The general aim of the present study is to analyze the need for such a common EU soil protection framework in view of existing soil-related policies. Addressing grand societal challenges justifies action on soil conservation at the European level (European added value). We therefore analyze the contribution of soil to society and the ways in which existing policies address soil. We identify gaps and overlaps that exist between those policies and whether there is a need for a new soil directive to replace the one that is currently withdrawn.

2. Materials and Methods

2.1. Analytical Framework

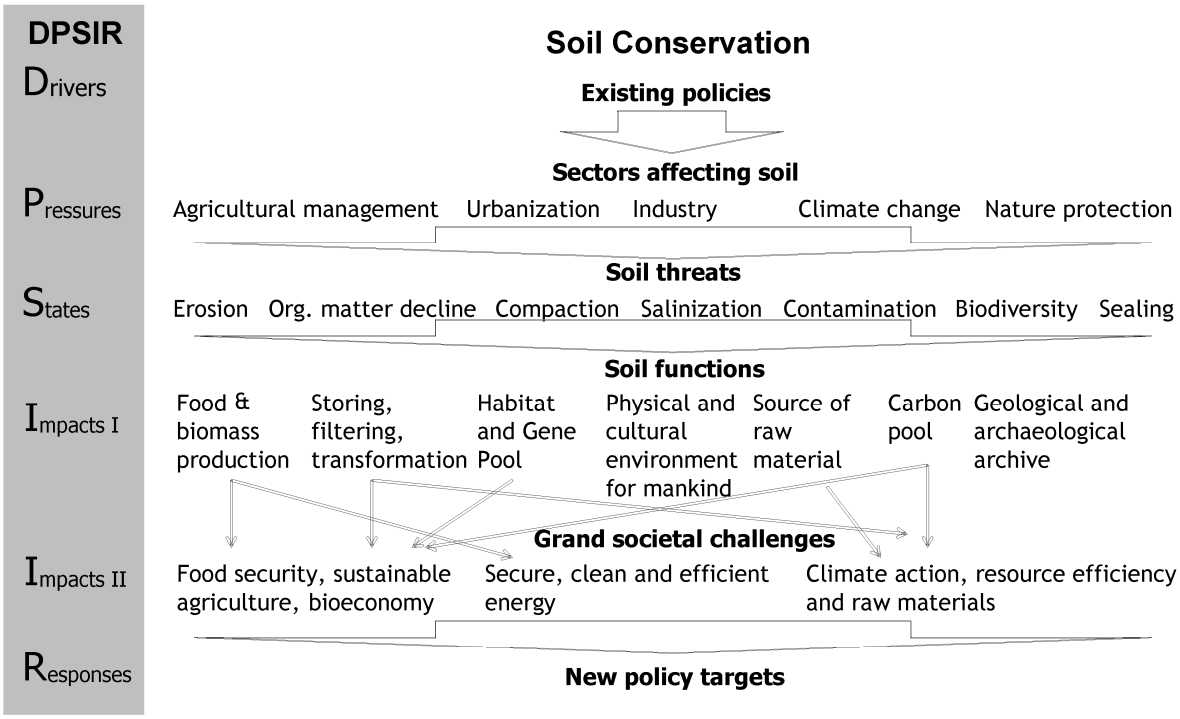
A policy analysis was carried out to assess the need for a separate soil directive at the European level. The analysis addressed the state of existing soil-related policies in terms of soil threats and soil functions and identified gaps and overlaps in soil protection in existing policies. The paradigm shift from soil degradation to the societal value of soil (which are both mentioned in the proposal for a Soil Framework Directive [3]) is the rationale behind using the concept of soil functions in combination with soil threats. Protection of soil resources plays a vital role in meeting the grand societal challenges. Therefore, the shift of focus from soil degradation (soil threats) to soil functions is relevant because of their relationship to the grand societal challenges at a European level (Figure 1).

Figure 1 shows how the DPSIR approach [29] is used to illustrate the links among existing policies (drivers of change) of sectors that affect soils (pressures) and soil threats (states), soil functions and grand societal challenges (impacts), as a way to address the need for new policy targets (separate legislation on soil conservation) (responses). Note that a DPSIR structure of policy evaluation had been mentioned in previous studies that were related to the implementation of a soil protection strategy [30–32], but those studies focused on a source-pathway-receptor approach, such as a health risk assessment, to support effective country-specific regulatory decisions for managing contaminated land [31]. We did not make this type of assessment in the present study. Rather, we evaluated the need for separate legislation on soil conservation by assessing whether existing policies adequately prevent or reduce soil threats and prevent the reduction of or improve soil functions in view of grand societal challenges.

The concept of soil functions connects physical, chemical and biological processes with the benefits of soil to society in environmental, economic and social terms. Similar concepts are "ecosystem services", which include provisioning, regulating, supporting and cultural services [17], and "landscape services", which was introduced as a bridge between landscape ecology and sustainable landscape development [33]. The term "soil functions" has been limited to agricultural soils by Schulte *et al.* [34], who distinguished five agricultural soil functions: (i) biomass production; (ii) water purification; (iii) carbon sequestration; (iv) biodiversity habitat; and (v) recycling of nutrients and agro-chemicals.

We have chosen to address all soils, not just those that are related to agriculture, so that we could use the soil functions concept that is mentioned in the proposal for a Soil Framework Directive [3].

Figure 1. The analytical DPSIR framework that links policies to soil threats [1], soil functions [2,16] and grand societal challenges (Horizon 2020).



2.2. Cross-Policy Analysis (Gap and Overlap Analysis)

A sector's having a direct relationship with soil constituted the criterion for policy selection. The main sectors that lead to soil degradation (pressures) fall into four main categories (Figure 1). The agricultural management category is related to the decline in soil organic matter, salinization, erosion and compaction as a result of biomass production for food, feed and energy. The industry category is related to the contamination that is associated with industrial sites; the urbanization category is related to soil sealing and land take for urban structures and infrastructure and for tourism; and the climate change category is related to greenhouse gas emissions and carbon pool changes. We therefore selected policies from these four sectors, as well as nature conservation policies for the analysis. Nature conservation policies were included in the analysis because of their role in preserving environment, including soil. A total of 19 legislative policies and two recent EC communications that were related to soil were analyzed (Table 1). Based on this analysis, gaps and overlaps in soil threats and soil functions that were addressed in existing policies were identified (Table 2). The criterion for inclusion was directly addressing a specific soil threat or soil function. Directives that may have indirect effects, such as livestock grazing, which results in greater soil compaction, were not included. A distinction was made between directives that "prevent acceleration" and those that "reduce" soil threats and similarly between those that "prevent reduction" or "improve" soil functions (Table 3). The analysis was related to the counterfactual issue that no policy (directive) was in place. The analysis was carried out at the EU level, therefore, national policies were not included.

Table 1. Policies analyzed in the study.

Policies	Number	Title
Agricultural policies		
Common Agricultural Policy (CAP)	1305/2013	European Agricultural Fund for Rural Development (EAFRD)
	1306/2013	European financing, management and monitoring of the common agricultural policy
	1307/2013	Common rules for direct support schemes
	1308/2013	European common organization of the markets in agricultural products
Plant Protection Products Directive	91/414/EEC	Concerning the placing of plant protection products on the market
Nitrates Directive	1991/676/EEC	Concerning the protection of waters against pollution caused by nitrates from agricultural sources
GMO Directive	2001/18/EC	Deliberate release into the environment of genetically-modified organisms
Pesticide Use Directive	2009/128/EC	Action to achieve the sustainable use of pesticides
Industrial policies		
Industrial Emissions Directive	2010/75/EU	Industrial emissions (integrated pollution prevention and control)
Landfill Directive	1999/31/EC	Landfill of waste
Mining Waste Directive	2006/21/EC	Management of waste from extractive industries
Biocidal Products Regulation	(EU) 528/2012	Concerning making available on the market and use of biocidal products
Waste Directive	2008/98/EC	Waste
Urban policies		
Sewage Sludge Directive	86/278/EEC	Protection of the environment and, in particular, of the soil, when sewage sludge is used in agriculture
Urban Waste Water Directive	91/271/EEC	Concerning urban waste water treatment
Climate policies		
Carbon Storage Directive	2009/31/EC	Geological storage of carbon dioxide
Renewable Energy Directive	2009/28/EC	Promotion of the use of energy from renewable sources
Nature conservation policies		
Habitat Directive	92/43/EEC	Conservation of natural habitats and of wild fauna and flora
Water Framework Directive	2000/60/EC	Establishing a framework for community action in the field of water policy
Air quality Framework Directive	2004/107/EC	Relating to arsenic, cadmium, mercury, nickel and polycyclic aromatic hydrocarbons in ambient air
Environmental Liability Directive	2004/35/CE	Environmental liability with regard to the prevention and remedying of environmental damage
Floods Directive	2007/60/EC	Assessment and management of flood risks
Non-binding EC communications		
Resource Efficiency Roadmap	COM/2011/571	Roadmap to a Resource Efficient Europe
7 EAP		7th Environmental Action Programme to 2020 "Living well, within the limits of our planet"

Table 2. Existing policies that directly address soil threats and soil functions.

Policies	Agricultural							Industrial				Urban			Climate		Nature conservation				Non-binding EC Communications		
	CAP	Plant protection products	Nitrates	Pesticide use	GMO	Industrial emissions	Biocidal products	Waste	Landfill	Mining waste	Urban waste water	Sewage sludge storage	Carbon energy	Renewable	Habitat	Framework Water	Floods	Framework Air quality	Environmental liability	roadmap	Resource efficiency	7 EAP
Year	2013	1991	1991	2009	2001	2010	2012	2008	1999	2006	1991	1986	2009	2009	1992	2000	2007	2004	2004		2011	2013
Soil threats																						
1. Erosion	X									X				X			X				X	X
2. Organic matter decline	X				X																X	X
3. Compaction																						
4. Biodiversity decline	X	X		X	X		X			X			X	X	X				X		X	X
5. Salinization																						
7. Contamination		X		X		X	X	X	X	X		X	X			X		X	X		X	X
6. Sealing																					X	X
Soil functions																						
1. Biomass production	X													X							X	X
2. Storing, filtering and transformation	X	X	X	X	X	X	X	X	X	X		X	X			X		X				X
3. Habitat and gene pool	X	X		X	X		X			X			X	X	X				X		X	X
4. Physical and cultural environment	X			X					X												X	X

Table 2. *Cont.*

Policies	Agricultural								Industrial				Urban		Climate		Nature conservation					Non-binding EC Communications		
	CAP	Plant protection products	Nitrates	Pesticide use	GMO	Industrial emissions	Biocidal products	Waste	Landfill	Mining waste	Urban waste water	Sewage sludge	Carbon storage	Renewable energy	Habitat	Water Framework	Floods	Air quality Framework	Environmental liability	7 EAP	Resource efficiency roadmap	
Year	2013	1991	1991	2009	2001	2010	2012	2008	1999	2006	1991	1986	2009	2009	1992	2000	2007	2004	2004	2013	2011	
5. Source of raw materials									X	X										X	X	
6. Carbon pool	X												X	X						X		
7. Geological and archeological archive	X								X								X					

Table 3. The number of existing European legislative policies that cover soil threats and soil functions and the resultant gaps in legislation. Policies are divided according to whether the policy "prevents acceleration of threat" or "reduces threat" and "prevents reduction of function" or "improves function".

Soil threats	Gap	Prevents acceleration of threat	Reduces threat	Policies involved
1. Erosion		2		• Renewable energy, mining waste
			2	• Floods, CAP
2. Decline in organic matter		2		• CAP, GMO
3. Compaction	**X**			
4. Loss of biodiversity		8		• Plant protection product, biocidal products, GMO [a], environmental liability, carbon storage, pesticide use, mining waste [a], renewable energy [a]
			2 [a]	• Habitat, CAP
5. Salinization	**X**			

Table 3. *Cont.*

Soil threats	Gap	Prevents acceleration of threat	Reduces threat	Policies involved
6. Contamination		12		• Waste, landfill, mining waste, pesticide use, plant protection products, biocidal products, environmental liability, carbon storage, water framework, air quality framework, sewage sludge, industrial emissions
			2	• Renewable energy, environmental liability
7. Sealing	**X**			
Soil functions	**Gap**	**Prevents reduction of function**	**Improves function**	**Policies involved**
1. Biomass production		2		• CAP, Renewable energy
2. Storing, filtering and transformation		13		• Nitrates [b], pesticide use [b], waste, landfill, mining waste, plant protection products, biocidal products, GMO, industrial emissions, carbon storage, water framework, air quality framework, sewage sludge
			1	• CAP [c]
3. Habitat and gene pool		8		• Plant protection product, biocidal products, GMO [a], environmental liability, carbon storage, pesticide use, mining waste [a], renewable energy [a]
			2 [a]	• Habitat, CAP
4. Physical and cultural environment for mankind		3		• Landfill [d], pesticide use, CAP
5. Source of raw materials		2		• Mining waste, landfill
6. Carbon pool		2		• CAP, renewable energy
7. Geological and archaeological archive		2		• CAP, floods

[a] None of these policies is directly linked to soil, but they all focus on biodiversity in general, [b] The Nitrates Directive, Pesticide use Directive (and CAP) focus on off-site impacts that improve this function in some areas of farms, but these activities also contribute to reducing the function by, e.g., the application of pesticides. Measures to prevent the reduction of this function in these directives are related to, e.g., buffer strips and not to the soil as a whole. [c] CAP includes measures for maintaining soil organic matter and soil structure, which indirectly improve soil Function 2. [d] The Landfill Directive prevents the reduction of this soil function in one area by preventing the location of landfills near residential and recreational areas and reduces the function (establishing residential and recreational areas) in other areas where a landfill is located.

3. Results and Discussion

3.1. States: Soil Threats

The existing soil-related policies that were identified in the cross-policy analysis as addressing soil threats and soil functions are presented in Table 2. The relationships of these existing policies to the states of soil threats are outlined below, as well as a discussion of the relevance of each soil threat and the extent to which it is covered in existing legislation. A summary of the results of the cross-policy analysis is presented in Table 3.

Soil Threat 1: Erosion

Soil erosion causes adverse on-site effects that include damage to land-based production (reducing crop yields) and loss of topsoil that is rich in nutrients and organic matter. It also causes adverse off-site effects that include blocking infrastructure and drainage channels, property damage, pollution of water bodies and destruction of wildlife habitats. The main pressures affecting the state of soil erosion are conversion to arable land, inappropriate land management, deforestation, overgrazing, forest fires and construction activities. Sites are especially at risk when incomplete plant coverage coincides with strong winds (wind erosion) or heavy rainfall (water erosion) [35,36].

Erosion is covered by four binding laws and two EC communications (Table 2). The Common Agricultural Policy (CAP) supports agricultural production, which tends to accelerate soil erosion. However, the CAP includes incentives for landowners to implement land management practices that limit soil erosion. A framework was established that set Good Agricultural and Environmental Conditions for land (GAEC). Those standards are intended to prevent soil erosion. Assessment and management of flood risk are set as targets in the Floods Directive. Management of flood risk is not related directly to soil erosion, but flood risk management implies the management of erosion control. The Renewable Energy Directive encourages conservation of areas that provide watershed protection and erosion control. The Mining Waste Directive states that construction of a new waste facility or modification of an existing waste facility must include measures that ensure that soil erosion that is caused by water or wind is minimized to the degree that is technically possible and economically viable, but the directive does not mention specific measures.

With regard to the non-binding EC communications, the Resource Efficiency Roadmap includes a milestone of the area of land in the EU that is subject to soil erosion of more than 10 tons per hectare per year should be reduced by at least 25% by 2020 and encourages Member States to implement actions that are needed for reducing erosion. The 7 EAP states that more efforts to reduce soil erosion are encouraged.

Hence, only the Floods Directive and a few measures of the CAP are the legislations that aim to reduce soil erosion. The Renewable Energy and Mining Waste Directives include only measures that are intended to prevent the acceleration of erosion (Table 3). On top of this, the Renewable energy Directive encourages the cultivation of crops (corn, oil seed, sunflowers) that are more erosive compared to wheat and prevents residues returning to the soil, which are an accelerator of soil erosion. More legislative emphasis on reducing soil erosion seems warranted because of the serious consequences of soil erosion.

Soil Threat 2: Decline in organic matter

Soil organic matter plays a vital role and is often defined as the most important indicator of soil quality, because it affects such physical, chemical and biological processes as water retention, nutrient cycling, contaminant retention and decay and providing habitat for soil organisms [37]. However, decline in soil organic matter is mentioned only in the CAP and the GMO Directive, as well as in the non-binding EC communications. The GAEC standards in the CAP are intended to maintain soil organic matter levels by means of appropriate practices, which include a ban on burning arable stubble. However, soil cultivation for agriculture itself reduces soil organic matter stocks [38]. The GMO Directive requires an environmental risk assessment before releasing genetically-modified organisms into the environment, and the assessment is to include potential changes in the soil decomposition of organic material. However, the GMO Directive relates only to changes in the decomposition of organic matter that might occur as a result of releasing genetically-modified organisms. Both the GMO Directive and the CAP place more emphasis on preventing the acceleration of the loss of soil organic matter than on reducing its decline (Table 3). Of the non-binding EC communications, the Resource Efficiency Roadmap includes a milestone that by 2020, soil organic matter levels should not be decreasing overall and should increase for soils with currently less than 3.5% organic matter. Furthermore, it encourages Member States to implement actions that are needed for increasing and restoring organic matter content in soils. The 7 EAP also mentions the need to enhance efforts to increase soil organic matter.

Soil Threat 3: Compaction

None of the existing EU laws and neither of the two EC communications address the threat of soil compaction (Table 2). The GAEC of the CAP touch upon appropriate machinery use for maintaining soil structure, but do not specifically target soil compaction. Compaction results from the mechanical stress that is caused by heavy agricultural machinery, especially during fertilizer application and harvesting [39,40]. Compaction can also be caused by repeated trampling by grazing animals. These activities expose the soil to high pressure that reduces its porosity, aeration and biological activity. Consequences include reduced water infiltration, increased water run-off, increased erosion and reduced crop root growth. Decreased root growth may substantially decrease water and nutrient uptake efficiency, which decreases food production [41,42]. Topsoil is loosened annually by tilling, but soil compaction increases over time [23]. Therefore, site-adequate management practices that address these pressures are required to reduce the threat of soil compaction.

Soil Threat 4: Loss of biodiversity

The diversity of above-ground plants and animals is addressed frequently in existing policies, but there is no specific focus on soil biodiversity. The relevance of these policies, which are intended primarily to prevent acceleration of biodiversity loss, is discussed in Section 3.2 under "Soil Function 3: Habitat and gene pool."

Soil Threat 5: Salinization

None of the existing EU laws and neither of the two EC communications address the threat of soil salinization (Table 2). Salinization occurs naturally in some European soils, but the accumulation of

salts results mainly from inappropriate irrigation practices [23]. Salinization is therefore expected to increase with the increased need for irrigation in response to climate change and anticipated increases in drought conditions, especially in Southern Europe [43], where salinization problems are already widespread [23]. Legislation that specifically targets the pressures of soil salinization would be useful, because salinization is likely to increase.

Soil Threat 6: Contamination

Contamination results from the use and presence of dangerous substances in industrial processes [44]. Contamination of soil is addressed in 13 existing legislative policies (Table 2), which is far more than any other soil threat. Directives regarding the disposal of wastes, which are the Waste, Landfill, Mining waste and Sewage sludge Directives, and directives regarding the application of chemicals, which are the Biocidal products Regulation and Plant protection and Pesticide use Directives, require that disposal and application of contaminants should be conducted in a manner that does not cause risks to soil. The Industrial emissions Directive addresses the prevention of emissions from entering soil. The Carbon storage Directive addresses the technology of CO_2 capture from industrial installations, its transport to storage sites and its injection into a suitable underground geological formation for permanent storage and ensures that there are no unwanted risks to the soil, such as deposition of impurities that are related to the technology. The Water Framework Directive addresses the identification and estimation of significant point-source pollution that originates from soils. Finally, the Air quality Framework Directive targets the effects of arsenic, cadmium, mercury, nickel and polycyclic aromatic hydrocarbons on human health and includes deposition limits to avoid accumulation of these substances in soil and related food chain impacts. All these directives are intended to prevent further acceleration of contamination, but none is focused on reducing this threat. The Renewable energy Directive recommends an increase in the amount of land that is available for biofuel cultivation by restoring heavily-contaminated land that cannot be used in its present state for agricultural purposes. The Environmental liability Directive also introduces the "polluter-pays" principle to prevent further soil contamination and measures for remediating land damage.

The two EC communications also address contamination. The Resource Efficiency Roadmap provides an inventory of contaminated sites and a schedule for remedial work by 2015, and it establishes a goal of remedial work on contaminated sites being well underway by 2020. The 7 EAP targets contamination by encouraging remediation of contaminated sites to be well underway by 2020.

However, 11 of the 13 directives aim only at preventing acceleration of soil contamination, because these directives derive from sectors that are pressures to soil contamination by applying waste or chemicals to soils. Only two directives (Table 3) address remediation of contaminated soil. The Renewable Energy Directive addresses the restoration of contaminated soil, and the Environmental liability Directive introduces remediation of land damage. Remediation of existing soil contamination is a relevant topic for legislation.

Soil Threat 7: Sealing

Sealing is both a soil function and a soil threat. Sealing serves urbanization (see "*Soil Function 4: Physical and cultural environment*"), but all other soil functions are lost when soil is permanently

sealed in the course of urban construction. Increasing land take due to urbanization threatens fertile soils throughout Europe [45].

None of the existing EU legislation addresses the threat of soil sealing (Table 2). However, the European Commission does acknowledge soil sealing in its two communications (Resource Efficiency Roadmap and 7 EAP), which both set targets of no net land take by 2050. An upcoming EC communication, which is titled "Land as a Resource", also includes this goal. The Resource Efficiency Roadmap further mentions the aim of reducing the annual land take from 1000 km² per year to 800 km² per year at the EU level by 2020. The Commission also launched "Guidelines on best practice to limit, mitigate or compensate soil sealing" (SWD(2012)101 final/2) in 2012 to confront the challenge of increasing land take by urban construction. Until now, there have been only strategies to address this soil threat, but there has been no binding legislation. Soil sealing would therefore be another important threat to address in legislative policies. Urban soils are, in general, a gap in existing legislation.

In summary, despite targets that are set in existing legislation for erosion control, organic matter decline, minimizing contamination and minimizing loss of biodiversity, these threats continue to cause soil degradation in all of the EU Member States. This raises questions about whether the existing legislation is sufficiently comprehensive and is effectively implemented in the Member States. Additionally, soil compaction, soil salinization and soil sealing are not addressed in binding legislation. Several laws do mention "sustainable management", which is a term that indirectly covers all threats to soil functions (including salinization, compaction and sealing). An earlier analysis of the indirect effects of existing legislative policies on the conservation of soils for agricultural production highlighted that existing policies have the potential to address all recognized soil threats across the EU [46]. However, we believe that it is crucial that policies address soil threats and soil functions directly to ensure that all soil threats and soil functions are managed. This includes targeting specific soil threats and functions to simplify and optimize the implementation of new soil management procedures that are intended to prevent soil degradation. There are many agricultural management options for preventing or reducing soil threats in Europe [38,47]. It goes beyond the scope of this paper to go into detail about existing conservation management practices. However, there is a lack of implementation, and the use of such general terms as "sustainable management" may hinder the establishment of specific goals for conserving soil resources.

3.2. Impacts: Soil Functions and Grand Societal Challenges

The seven soil threats are very closely linked to the seven soil functions, because each soil threat leads to decreased functions of soil (Figure 1). Hence, in maintaining soil functions, all soil threats must be addressed. Shifting the policy paradigm from soil threats to soil functions addresses the values of soil for society and, therefore, better justifies policy action for maintaining and supporting soil functions. This is because it also lays focus on the public good character of soil processes and services, rather than private goods, which are only of value to the land owners. However, the concept of soil functions is less specific than the concept of soil degradation processes. We therefore believe that the focus of soil protection should be based on soil functions and that the targets should be based on soil threats, because it is the threats that impact soil functions (Figure 1).

Soil Function 1: Food and biomass production

The most obvious function of soil is the production of food for people and feed for farm animals. This relates to the grand societal challenges of food and energy security and sustainable agriculture (Figure 1). The need to produce food is increasing, because globally, productive arable soils will have to satisfy the needs of nine billion people by 2050, with an estimated increase in the demand for food production by around 70% [48,49] or even 100% [50]. In addition to providing food and feed, soil is the resource for meeting the increased demand of the growing world population for non-food biomass that is dedicated to energy and fiber products. One of the key challenges for soil protection is to simultaneously conserve soil while increasing productivity to ensure food security and provide bio-energy.

The CAP is the most important document for addressing agricultural food and biomass production. The CAP promotes increased production of agricultural products, and this has been its main focus. However, the focus has changed to include more measures for sustainability. The "greening" of the new CAP (which is planned for the period 2014–2020) will include additional support for farmers that implement management practices or establish ecological focus areas that benefit the climate or the environment. This coincides with GAEC standards that are intended to contribute to the maintenance of the landscape, water protection, climate action and management practices that increase the levels of soil organic matter and prevent soil erosion (see above). The Renewable energy Directive provides direct support for farmers by requiring that the GAEC standards also apply to biofuel production. This Directive attempts to assess the impacts of the competing demands of food and biofuel production. The Directive encourages restoration of severely degraded or heavily contaminated land that cannot be used in its present state for food production purposes.

In addition to these laws, the two EC communications, (the Resource Efficiency Roadmap and 7 EAP) both mention that high biomass production must be maintained to meet the increasing demand for agricultural products. Both communications promote sustainable management of agricultural production to ensure protection of soil resources. The 7 EAP includes a specific target that all land in the EU is to be managed sustainably, and soil is to be protected adequately by 2020. The Resource Efficiency Roadmap recommends the development of "innovation partnerships" that meet resource efficiency goals that pertain to productive and sustainable agriculture.

Because agricultural productivity is so specific, it is addressed only in policies that address biomass production, although almost all directives mention arable land. The incentives for GAEC that are included in the CAP and in the Renewable energy Directive are intended to prevent a reduction of this function. However, because all soil threats are applicable to agricultural productivity (Figure 1), it is crucial to target reductions in all soil threats to maintain and improve this soil function in the future. In addition, contrary to the targets of the Renewable energy Directive, the analysis of its implementation has shown that it creates trade-offs that compromise soil quality and reduce the soil function of biomass production in the long run [51].

Soil Function 2: Storing, filtering, transformation

The storing, filtering and transformation function of soil refers to the role of soil as a storage reservoir for nutrients and wastes, as a filter for water and air contaminants and as a transformation medium for chemicals. Water quality is particularly dependent on this soil function, because chemical inputs to soil may cause severe water pollution if they are not captured by the soil [52]. This function

serves all of the grand societal challenges that are related to soil, which include food and energy security, climate action and resource efficiency (Figure 1). Storing, filtering and transformation is the single soil function that is most commonly addressed by existing policies (Tables 2 and 3). These three processes are discussed separately here.

Many of the directives address the storage function, including waste deposition on land (Waste, Landfill, Mining waste, Sewage sludge and Urban waste Directives, although the latter directive does not directly address soil or land), industrial emissions (Industrial emissions Directive) and the technology of CO_2 capture and geological storage (Carbon storage Directive). These directives, which all utilize the storage function of soil, target the avoidance of soil contamination for preventing a reduction in the function, but they do not target the maintenance of the soil function.

The filtering function is addressed in the Water Framework, Nitrates, Air quality Framework and Pesticide use Directives and in the CAP. These laws address soil as a filter for water and air purification. The Water Framework Directive requires identification and estimation of significant point-source pollution from urban and industrial sites and regional pollution from agricultural land, but only the Nitrates Directive and the CAP specifically address water pollution from agricultural sources. Agricultural management practices (GAEC), such as introducing buffer strips to protect waterways from pollution from agricultural runoff, are mentioned in the CAP, Nitrates Directive and Pesticide use Directive. These directives directly target maintenance of the filtering function of soil, but their focus is on off-site impacts, *i.e*., avoiding contamination of soil or water bodies. No policy targets on-site impacts.

The transformation function is addressed in the Plant protection products Directive and Biocidal products Regulation (in relation to products that have disinfectant, preservative and pest-controlling properties). These directives address toxic chemicals and ensure the authorization of only those products that have no unacceptable effects on soil. It requires that ecotoxicological studies be carried out with respect to degradation, adsorption/desorption, mobility and the possibility of destruction or decontamination following the release of the products into soil. The GMO Directive requires an environmental risk assessment of the effects of releasing genetically-modified organisms on biogeochemical cycles, specifically on carbon and nitrogen recycling. These directives, which recognize the regulating function of soil, are intended to minimize the effects on soil and, therefore, can then be described as preventing a reduction of the function. However, they do not target the maintenance or improvement of this soil function.

The 7 EAP includes recommendations to integrate water protection into planning and decisions that are related to land use by reducing nutrient release from inefficient fertilizer management and inadequate wastewater treatment. The 7 EAP encourages investment in research and improvements in the coherency and implementation of Union environmental legislation to achieve these protective measures. The communication also recommends phasing out the deposit of recyclable or recoverable waste in landfills and more sustainable and resource-efficient management of the nutrient (nitrogen and phosphorus) cycle by 2020.

The storing, filtering and transformation function is mentioned in most policies, because this soil function is relevant to many sectors of land use. The goal in all of these policies is to protect soil resources (soil quality or avoiding soil contamination) by preventing the reduction of the function of soil as a medium that stores, filters or transforms contaminants to avoid risks to soil. However, simply avoiding contamination is not sufficient for improving the storing, filtering and transformation

function in the future. This soil function is largely dependent on physical, chemical and biological properties, such as carbon content, soil pH and ground water level. Soil conservation measures are therefore needed for maintaining and improving this soil function over the long run. The CAP is intended to contribute to a minimum level of maintenance of this function by preventing soil erosion and maintaining soil organic matter and soil structure, particularly in high-threat areas.

Soil Function 3: Habitat and gene pool

Loss of biodiversity is receiving increased global awareness, but the biodiversity of soil is rarely considered. There is increased scientific interest in soil biodiversity, because soil provides habitats for many organisms, and many of functional traits of soil are yet to be discovered [53,54]. Such scientific interest includes platforms, such as globalsoilbiodiversity.org, as well as European Atlas of Soil Biodiversity (http://eusoils.jrc.ec.europa.eu/library/Maps/Biodiversity_Atlas/). Soil organisms play an important role in the release and/or retention of nutrients during the decomposition of organic matter. These organisms affect soil fertility and food production and, therefore, serve the grand societal challenge of food security (Figure 1). Soil biodiversity indisputably provides soil resistance and resilience against disturbance and stress, but the extent and dynamics of these effects are not completely understood [55]. Increasing attention is being given to the role of functional soil biodiversity, as contrasted with species diversity, for the provision and stability of soil processes and functions [53,54,56]. The soil fauna additionally serves as a large gene pool that could be a source of new drugs to fight infectious human diseases.

Several of the policies that we examined are intended to preserve biodiversity in general, but they do not mention soil biodiversity. The Habitat Directive includes the establishment of a coherent ecological network of special areas for the conservation of natural habitats and for the protection of wild fauna and flora within the EU (Natura, 2000). Member States are required to establish conservation measures to prevent the deterioration of natural habitats in these areas and to prevent the disturbance of the species for which the areas have been designated. The CAP supports agricultural practices and mitigation strategies that protect, improve, restore, preserve and enhance biodiversity. These include conservation practices in special areas (Habitat Directive) and establishment of ecological focus areas to safeguard and improve biodiversity on farms. These ecological focus areas should consist of areas that directly affect biodiversity, such as fallow land, landscape features, terraces, buffer strips, afforested areas and agroforestry areas, or that indirectly affect biodiversity by means of reduced use of inputs on the farm, such as areas that are covered by catch crops (fast-growing interseasonal crops) and green winter cover. Payments are given to farmers that convert to or maintain organic farming and to forest holders that provide environmentally-friendly or climate-friendly forest conservation services that are intended to enhance biodiversity. The CAP supports the exchange of best practices, training and capacity building and demonstration projects that relate to biodiversity. This is emphasized for projects that relate biodiversity and agroecosystem resilience, as contrasted with monocultures that are susceptible to crop failure or damage from pests and extreme climatic events. Although the Habitat Directive and the CAP are intended to improve biodiversity, they do not directly address soil biodiversity and, therefore, do not address the soil function, habitat and gene pool.

Many of the policies mention risk to fauna and flora. The GMO Directive addresses the long-term effects that the release of genetically-modified organisms have on the environment and on biological

diversity and nontarget organisms. The Environmental liability and Mining waste Directive assesses the risks that are posed by harmful substances to organisms in the environment. The Renewable energy Directive does not target soil biodiversity directly, but it does target conservation of biodiversity in general by means of incentives when it can be proven that biofuel production does not originate in biodiverse areas (habitats). The Carbon storage Directive mentions that proximity to habitat conservation areas (as specified in the Habitat Directive) should be considered when choosing a new storage site. This directive additionally requires sensitivity tests on particular species that would be affected by leakage events. The tests involve the effects of elevated CO_2 concentrations, reduced soil pH and the effects of other substances that may be present in leaking CO_2 streams. Laws that apply to chemical substances, such as the Plant protection products Directive and the Biocidal products Regulation, ensure that authorization of chemicals occurs only after toxicity tests on the active substance, degradation products and additives show that there are no unacceptable effects on earthworms and other nontarget soil macro- and micro-organisms. The Plant protection products Directive additionally requires toxicity tests on soil microflora. The Pesticide use Directive promotes integrated pest management by means of such agricultural practices as crop rotation and biological control to suppress harmful organisms by low-pesticide pest management. Additionally, pesticides that are applied are required to be as target-specific as possible and have the fewest side effects on nontarget organisms and the environment. Note that none of these directives is intended to increase biodiversity. They are instead intended to reduce the deterioration of its function.

The Resource Efficiency Roadmap supports innovative solutions for the preservation of biodiversity and sets as a goal that improved efficiency in the transport sector will deliver reduced impacts on biodiversity by 2020. The Resource Efficiency Roadmap also supports increased biodiversity by means of good farming practices. Finally, the 7 EAP recommends the integration of biodiversity conservation into land-use planning and decisions. These non-binding EC communications also relate only to biodiversity in general and not specifically to soil biodiversity.

The habitat and gene pool function is frequently addressed in existing legislation (Table 2), but the targets of these laws are related to improving biodiversity in general and not to soil organisms (Table 3). The CAP includes measures for enhancing and improving biodiversity on farms, but it must be remembered that conventional agricultural production itself accelerates biodiversity decline. The policies that do target soil organisms address only the prevention of harm to nontarget organisms when, for example, plant protection chemicals are used. They do not address the decline in soil biodiversity or the need to maintain populations of organisms that are beneficial to soil. However, it is difficult to capture this aspect in legislation, because there is little knowledge of the significance of soil organisms and the diversity of functional traits among soil microbial communities. Neglecting soil biodiversity may have severe impacts on most of the other functions of soil (Figure 1). Addressing biodiversity in general and not soil biodiversity in these laws and communications neglects the abundance of soil organisms and their importance for soil quality [54].

Soil Function 4: Physical and cultural environment for mankind

The function of the physical and cultural environment for mankind relates to urbanization, recreational areas and nature tourism. This function is therefore strongly linked to land take, which is

increasing rapidly in all Member States of EU [45]. This function does not relate directly to any of the grand societal challenges.

The CAP addresses rural development, which includes the creation and development of new economic activities that are related to healthcare and tourism in rural areas. The CAP also supports the development of local infrastructure and basic services in rural areas, which include leisure and culture services and renewal of villages. The Pesticide use Directive addresses this function by minimizing or prohibiting the use of pesticides in areas from which drinking water is extracted, along transport routes, on sealed or very permeable surfaces, in public parks, recreation grounds, school grounds and children's playgrounds and in proximity to healthcare facilities. This directive targets protection against pollution of areas that act as physical and cultural environments for mankind and, therefore, prevents the reduction of this soil function. The Landfill Directive also considers the distance from residential and recreational areas when locating landfills.

The Resource Efficiency Roadmap and the 7 EAP both target the growing issue of land take due to urbanization, and both have set a target of no net land take by 2050, as mentioned above under "Soil Threat 7: sealing".

This function is not mentioned extensively in soil-related policies. However, with the current trend of increasing land take [45], this function is not under threat, but is rather threatening the other functions, because this function often results in losses of other functions. For example, there are measures in the Landfill Directive that prevent the reduction of this soil function in one area by not locating landfills close to residential and recreational areas, but this reduces the soil function (establishing residential and recreational areas) in other areas where a landfill is already located. A recent study addresses how the impact of land take affects other functions, specifically food production [57]. They estimated that 19 EU countries lost approximately 0.81% of their potential agricultural production capacity between 1990 and 2006, with large variability between regions. Regions around the largest cities experienced the greatest loss of fertile soils [57].

Soil Function 5: Source of raw materials

Soil also functions as a source of minerals, fertilizers, gravel and other elements that are extracted or excavated by different industries. The grand societal challenge of resource efficiency and raw materials (Figure 1) requires proper and efficient use of this soil function. Development in the past century has been based on the ever-increasing use of natural resources. However, reduction in the current patterns of consumption is necessary if irreversible depletion of soil resources is to be avoided [58].

The Landfill and the Mining waste Directives both address preservation of soil as a source of raw materials. The Landfill Directive is intended to make the wasteful use of land unnecessary by encouraging prevention, recycling and recovery of waste and use of recovered materials in a resource-efficient way. The Mining waste Directive prohibits abandonment, dumping or uncontrolled deposition of extractive waste by putting it back into the space that was created by excavation after minerals have been extracted, by putting topsoil back in place after a waste facility is closed or by reusing topsoil elsewhere.

Under the Resource Efficiency Roadmap, the Commission will develop "innovation partnerships" for meeting resource efficiency goals that pertain to raw materials and will focus on Union research funding (EU Horizon 2020) and on key resource efficiency objectives that support innovative solutions

for the management of natural resources and environmentally-friendly material extraction. The roadmap additionally sets milestones of no net land take by 2050, assuring a sustainable supply of phosphorus and reversing soil loss. It also promotes efficiency in the transport sector with optimal use of resources, such as raw materials, by 2020. The 7 EAP sets a goal of more sustainable and resource-efficient management of the nutrient (nitrogen and phosphorus) cycle.

The source of raw materials is not covered extensively in these soil-related policies. The mining industry promotes reuse of waste, but the mining directive is targeted only at the prevention of reduction of this soil function (Table 3). The rationale for improving soil that serves as a source of raw materials is unclear unless further extraction is prevented. In fact, a recent study considered the extraction of raw materials as a soil threat rather than a soil function [12].

Soil Function 6: Carbon pool

Soil has been estimated to store globally 1500 Gt of carbon [59] with 73 Gt of carbon stored in European topsoils [25] and 17.63 Gt in agricultural topsoils in Europe [60]. Soil carbon sequestration is especially important for the mitigation of the grand societal challenge of climate change (Figure 1). Carbon storage by soil is also very important for soil fertility, which ensures food and energy security (other grand societal challenges, Figure 1). Peatlands store particularly large amounts of carbon, and conversion of peatlands to arable land releases vast amounts of CO_2 into the atmosphere [60,61]. A comprehensive study has been carried out on estimating the effect of different agricultural management practices on the carbon sequestration of topsoils in Europe [60].

The CAP supports carbon sequestration in soil and maintenance of high organic matter levels in soil. However, an analysis of the CAP by Henriksen *et al.* [51] reports that although GAEC is an important component to encourage soil management practices for mitigating carbon stocks, there are failures of implementation in Member States. The Renewable energy Directive addresses the soil carbon pool by allowing land conversion for biofuel production only if the loss of soil carbon stock that is caused by conversion can be remediated by savings in greenhouse gas emissions that accrue from biofuel production within a reasonable period. The Commission provides incentives for sustainable biofuel production that minimizes the impacts of land use change. The directive attempts to avoid a net increase in arable land and related carbon losses by encouraging increased productivity on land that is already used for crops and encouraging the use of degraded land for biofuel production. Further, biofuel production is not allowed on land that has high carbon stocks, such as wetlands and forests. It should be noted that both the CAP and the Renewable energy Directive are intended to prevent the reduction of the soil carbon pool, but do not improve this function (Table 3). Additionally, the Renewable energy Directive implies that such carbon sources as crop residues, animal manure and other types of organic waste are not returned to the soil, which reduces the carbon pool of the soil.

To combat climate change, the Carbon storage Directive establishes a legal framework for environmentally safe geological storage of CO_2. However, this directive relates only to CO_2 storage in deep geological formations and is therefore not directly related to what is usually understood to be soil (for example, agricultural topsoil) that is involved in the soil carbon storage function. This is similar to the manner in which this directive addresses Soil Threat 2, organic matter decline of soils (Table 2).

The 7 EAP includes targeted priority objectives to sequester CO_2.

At a global level, the Kyoto protocol aims to protect and enhance greenhouse gas reservoirs and CO_2 sequestration technologies. The protocol states that countries shall formulate, implement and publish measures to mitigate climate change and to facilitate adequate adaptation to climate change. These efforts are to be based on the assessment of net changes in carbon stocks by sources and removals by sinks resulting from direct human-induced land use change and afforestation, reforestation and deforestation.

Soil Function 7: Geological and archaeological archive

Soil provides a geological and archaeological archive of natural and human history.

The CAP mentions preservation of the archaeological archive in the Rural Development Policy, which promotes protection of natural and cultural heritage by means of sustainable and responsible tourism in rural areas. The Floods Directive recommends establishment of a framework to assess and manage flood risks to reduce the adverse effects of floods on human health, the environment, cultural heritage and economic activity in the EU. The Landfill Directive addresses the protection of natural and cultural patrimony when locating landfills.

The geological and archaeological archive affects multiple sectors, but is not frequently mentioned in the policies that we reviewed. This may result from less public awareness of this function, because it is not mentioned in the media as often as, for example, biodiversity loss and climate change or because this soil function is not directly linked to the grand societal challenges (Figure 1).

In summary, all soil functions are addressed by existing legislation, but the usual focus is on the way in which soil currently serves a particular function and how to prevent a reduction of that particular function. Very few policies include targets that would improve the functions of soils over the long run (Table 3). Only nature conservation policies address maintenance and improvement of soil functions in a long-term perspective. The CAP includes some improvement strategies and does recommend a European innovation partnership (EIP) that would facilitate the establishment of pilot projects that would be related to soil functionality. However, as mentioned above, the CAP uses the nonspecific term "sustainable management" and does not directly address the specific threats to soil functions or provide specific targets for improving or maintaining soil functions. Other studies [62] have also criticized the subjectivity of the term "sustainable soil management." Further, the CAP is based on incentives that are given to farmers, and its provisions are not legally mandated. This results in the implementation of only some of the recommendations. It also implies that farmers would lose incentives that are important for their livelihoods if sustainable land use were to be made mandatory. Farmers also receive incentives for practices that prevent the acceleration of one soil threat even though those practices may cause the acceleration of other soil threats. For example, reduced tillage reduces erosion, but may increase contamination by increasing pesticide input [63].

4. Conclusions: Responses in Light of New Policy Targets

This cross-policy analysis shows that three of the seven soil threats, compaction, salinization and sealing, are not covered by existing legislation. Compaction and salinization are also not addressed in the EC communications. The decline in soil organic matter is barely mentioned. Biodiversity in general is addressed, but soil biodiversity is also barely mentioned. Soil erosion and especially soil

contamination are two threats that are frequently addressed in existing legislation (Table 2). However, the analysis showed that almost all of the policies are intended to 'prevent acceleration of threats', but only a few target a reduction of the threats (Table 3).

The failure to address all seven soil threats threatens soil functions. The analysis also showed that all soil functions are addressed in the existing legislation, but nearly all of the directives are intended to prevent the reduction of a particular soil function. Few directives are intended to improve soil functions in the future (Table 3). It is therefore unclear if existing soil-related legislation is actually protecting the soil from soil threats and improving a soil function. Soil degradation is ongoing in Europe [23], which suggests that existing policies are not sufficient for maintaining soil functions. There appears to be a need for a new common, soil conservation policy at the European level. Soil degradation exists throughout the EU, but only a few Member States have enacted comprehensive national soil legislation [64]. The existing national soil protection laws of those Member States will not be threatened by common EU legislation, because Member States may adopt laws that are more protective than EU legislation. There are transboundary aspects of soil degradation even though soil is generally immobile; these include erosion, chemical contamination and international markets. European added value would also include the fact that common EU legislation would benefit internal market issues in cases where some Member States have strong soil conservation policies and others do not. Common legislation would also facilitate the export of expertise and technologies from the EU. The costs of inaction may surpass the costs of action within only a few years [65]. Furthermore, the cost of soil degradation is challenging due to both direct, indirect and non-use values of soil [62]. A further limitation for addressing the cost of soil degradation is the limited soil function monitoring [62]. When directives address soil functions individually, they neglect the multifunctionality of soil. Sustainable land use is often based on the multifunctionality of land or soil and is intended to maintain all soil functions [66]. Indeed, the specific functions of soil are site-specific and depend on the natural potential of soil to provide these functions. Often, these functions can be mutually exclusive, leading to trade-off situations. The multifunctionality of soil may be lost when soil functions are addressed separately in different directives.

A directive that is focused exclusively on soil might also be useful in the case of new technologies that affect soil (e.g., fracking). Common legislation could protect soil before specific laws that are related to new technologies can be passed.

Policy legislation and planning that maintain the non-economical functions of soil over the long run are required to ensure comprehensive soil functions. The policy legislation could be in the form of a Soil Framework Directive. This paper emphasizes that a common European soil conservation policy would provide added value to the EU by addressing the grand societal challenges that have been set forth by the European Commission. An IA based on soil functions provides the direct link to the societal value of soils and may better justify soil legislation. We believe that policies must address soil threats and functions directly to ensure that the threats and functions are targeted by new sustainable soil management practices. Because existing legislation fails to address soil threats and functions directly, a common European soil policy is needed to ensure the conservation of soil functions.

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Conflicts of Interest

The authors declare no conflict of interest.

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